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BREEDING RATES OF EURASIAN KESTRELS (*FALCO TINNUNCULUS*) IN RELATION TO SURROUNDING HABITAT IN SOUTHWEST SPAIN

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Abstract.—We studied breeding success of Eurasian Kestrels (*Falco tinnunculus*) in nest boxes in seven different habitat types in the southwest of Spain. A total of 567 nest boxes was installed on power pylons in fallow fields, cereal cropland, holm oak land, olive orchards, pastureland, irrigated cropland, and shrubland. Occupation of boxes did not vary among the habitats and there were no significant differences among the seven habitat types in laying date, clutch size, or breeding success. When habitats with low numbers of breeding pairs were removed from analyses, we were able to detect significant differences in mean laying dates, clutch sizes, and breeding success rates among the three habitat types with the highest sample sizes. Kestrels nesting in pastureland showed higher clutch sizes and higher breeding success that those nesting in the cerealland. A seasonal decline in clutch size was found in all three habitat types with the highest sample sizes. Our results suggested that habitat features influence the breeding biology of Eurasian Kestrels.

Key Words: *Eurasian Kestrel*; Falco tinunculus; *habitat features*; *breeding success*; *agricultural intensification*; *Spain.*

Tasas de reproducción de *Falco tinnunculus* en relación al habitat circundante en el suroeste de España

Resumen.—Se ha estudiado la influencia del habitat de nidificación sobre la biologia reproductora del Cernícalo Vulgar Falco tinunculus en una población reproductora del sudoeste de España. Se instalaron en postes de líneas de conducción eléctrica 567 cajas-nido dentro de siete tipos diferentes de hábitats: Barbechos, siembras de cereal, dehesas arboladas de encinas, olivares, pastizales, cultivos de regadío y áreas con cobertura de matorral. No existieron diferencias significativas en los porcentajes de ocupación de los nidales entre los siete habitats. No se detectaron diferencias entre los siete hábitats en la fechas medias de puesta, tamaños de puesta y tasas reproductoras de los cernícalos. Sin embargo, cuando se extrajeron de los análisis aquellos hábitats con menor número de parejas nidificantes, existieron diferencias entre hábitats en el inicio de la reproducción. Del mismo modo, el tamaño de puesta y el éxito reproductor variaron entre los tres hábitats con mayores tamaños muestrales. Los cernícalos que nidificaron en pastizales tuvieron mayores tamaños de puesta y mayor éxito reproductor que los que lo hicieron en cultivos de cereal. En los tres hábitats con mayor tamaño muestral se detectó un descenso estacional del tamaño de puesta que no varió entre los hábitats. Los resultados sugieren la influencia de los rasgos del hábitats sobre la biología de reproducción de la especie en nuestra zona de estudio.

[Traducción de Autores]

European Kestrel (*Falco tinnunculus*) populations are declining in the Palearctic because of the intensification of agriculture (Village 1990, Shrubb 1993). In Spain, the breeding population has remained stable since the 1970s at 25 000–30 000 pairs (Aparicio 1997). Although this population has been used as a tool in experimental studies (Aparicio 1994a, 1994b, 1998), there is little information on its basic biology. Some studies have reported breeding rates (Aparicio 1994a, Gil-Delgado et al. 1995, Avilés et al. 2000), but almost nothing is known about its breeding biology in different habitats in the Iberian Peninsula.

Nest boxes are readily accepted by kestrels (Village 1990). Although care should be taken when testing hypotheses related to fitness in such artificial nesting situations (Møller 1989), nest boxes offer an exceptional opportunity to conduct breeding studies in cavity-nesting species of birds (Clutton-Brock 1988). The aim of this study was to test the effect of habitat type on the breeding performance of Eurasian Kestrels in the Serena region in the southwest of Spain.

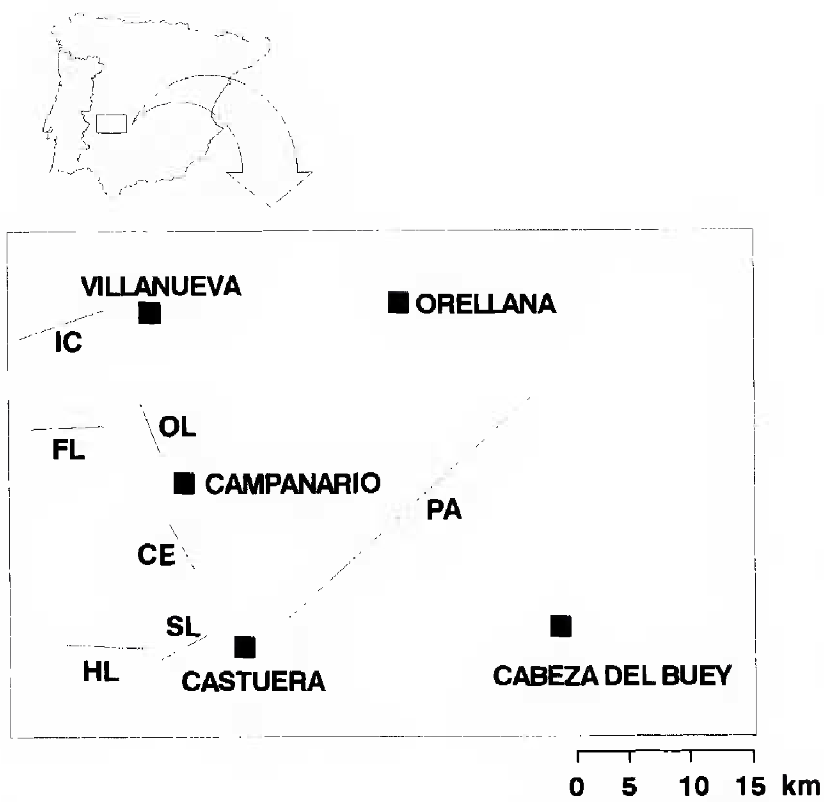

Figure 1. Map of the location of the study area and the length of electric power lines (lines) in each habitat type. Squares represent the major towns in the Serena region. Codes for habitat types are: fallowlands (FL), cereal croplands (CE), holm oaklands (HL), olive orchards (OL), pasturelands (PA), irrigated croplands (IC), and shrublands (SL).

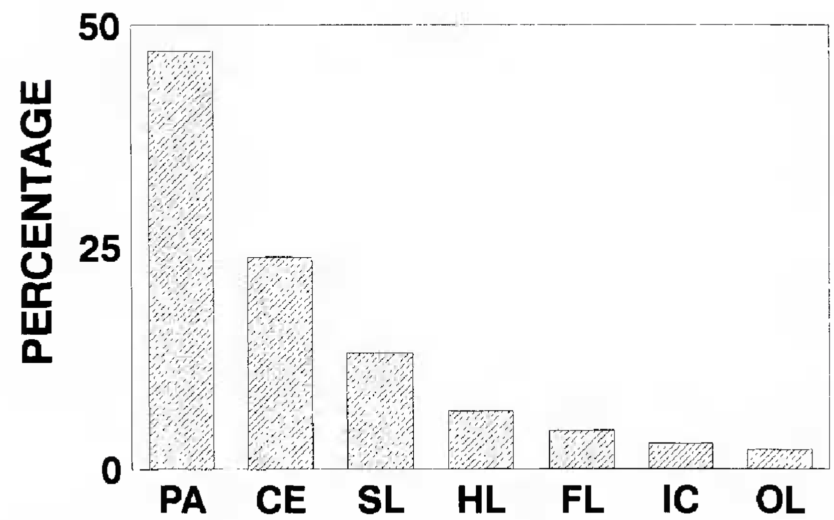

Figure 2. Percent distribution of nest-boxes used by breeding Eurasian Kestrels in relation to habitat type. Codes for habitat types are: pasturelands (PA), cereal croplands (CE), shrublands (SL), holm oaklands (HL), fallowlands (FL), irrigated croplands (IC), and olive orchards (OL). Habitats are ordered in relation to their nest box use.

STUDY AREA AND METHODS

The study area was located in the Serena region of Spain (39°03′N, 5°14′W). The climate of the area is Mediterranean and mean temperature and rainfall during May and June is 17.7°C and 11.6 mm, respectively (Avilés et al. 2000). In February and March of 1989, 567 nest boxes were installed on all the power pylons that crossed patches of seven different habitats in the study area: fallowlands (N = 26 nest boxes), cereal croplands (oats, wheat, and barley, N = 159 nest boxes), holm oaklands (*Quercus rotundifolia*) (N = 63 nest boxes), olive orchards (N = 14 nest boxes), pasturelands (N = 237 nest boxes), irrigated croplands (rice and maize, N = 18 nest boxes), and shrublands (mainly *Retama sphaerocarpa*, N = 50 nest boxes) (Fig. 1). Habitat patches with possible natural cavities (holm oakland and olive orchards) and farmhouses with possible nesting sites were searched for pairs of breeding kestrels but we did not find any kestrels breeding in natural cavities. We considered a patch of habitat to accurately represent kestrel breeding parameters when all the boxes in it were surrounded at least by 1 km of this same habitat type. The minimum distance between two patches was 1.5 km between holm oaklands and shrublands (Fig. 1). Although we did not make observations of hunting activities of the kestrels, we considered 1 5 km to be a reasonable estimation of the hunting territories taking into account the fact that breeding kestrels forage at a maximum distance of 2 km from their nests in Spain (Veiga 1982). We did not expect any density-dependent effects on kestrel breeding performance because the mean (±SD) density of nest boxes was 9.43 ± 0.26 boxes/km of power line independent of habitat type, and the percent of boxes occupied by kestrels in all seven habitats was <50% (Fig. 2).

All the boxes were monitored weekly from the first stages of breeding in 1989. We assumed that nest-box availability in each habitat type did not affect breeding of kestrels because the interhabitat distribution of nest boxes and breeding pairs of kestrels did not vary (G-test G_6 = 5.96, P = 0.42), Eurasian Rollers (*Coracias garrulus*) that also use nest boxes began egg laying in our study area at least 1 mo later than kestrels (Avilés et al. 1999), and there was no evidence of damage to kestrel eggs or young by rollers when kestrels were the first to breed in nest boxes (Cramp and Simmons 1980, Avilés pers. obs) In boxes occupied by kestrels, nest visits were increased to one visit every 3–4 d during the nesting period to determine breeding success accurately. Laying dates were determined by subtracting the incubation period from the hatching date (Cramp and Simmons 1980). When determining hatching dates, we took into account the fact that the laying interval in the species is two days (Cramp and Simmons 1980). We measured percent hatching success as the percent of eggs in each clutch that hatched, the number of fledglings per successful nest with successful nests being those at which at least one young fledged, and breeding success as the number of fledglings per pair that laid at least one egg.

We checked for interhabitat differences in the percent of boxes used using a contingency table with a Chi-square test. Normality of the variables was checked with Kolmogorov-Smirnov tests. Any nonnormality in differences in laying dates, clutch size, and breeding rates among habitat types was checked with Kruskal-Wallis tests. Differences between pairs of habitats were tested using nonparametric Tukey-type multiple comparisons. Seasonal declines in clutch size were analyzed using two-tailed Spearman correlations. We checked for interhabitat differences between clutch sizes and laying dates based on the comparison of correlation coefficients from independent samples (Zar 1996).

RESULTS

The percent of nest boxes used by nesting kestrels ranged from 47.1% in pasturelands to 2.17% in olive orchards, but it did not vary significantly among the seven habitats in our study ($\chi^2_6 = 7.55$, $P = 0.27$) (Fig. 2). Likewise, no significant differences between the seven habitat types were detected in mean laying dates ($H_6 = 11.4$, $P = 0.08$, $N = 88$), clutch sizes ($H_6 = 8.8$, $P = 0.83$, $N = 136$), hatching success ($H_6 = 3.9$, $P = 0.67$, $N = 123$), breeding success ($H_6 = 8.8$, $P = 0.82$, $N = 125$), or fledgling success ($H_6 = 7.65$, $P = 0.26$, $N = 115$) (Table 1).

Because our results were probably influenced by the low number of breeding pairs in fallowlands, olive orchards, holm oaklands, and irrigated croplands, we tested for differences in breeding parameters in the three habitat types with the largest sample sizes: cereal croplands, pasturelands, and shrublands. We found significant differences in mean laying dates ($H_2 = 9.47$, $P = 0.008$, $N = 73$), clutch sizes ($H_2 = 6.17$, $P = 0.04$, $N = 114$), and breeding success rates ($H_2 = 7.01$, $P = 0.02$, $N = 108$), but not in hatching success ($H_2 = 0.91$, $P = 0.63$, $N = 106$) and fledglings per successful nest ($H_2 = 4.14$, $P = 0.12$, $N = 100$) (Table 1). Pairs nesting in boxes in pasturelands showed a higher clutch size and a higher breeding success than those nesting in cereal croplands ($P < 0.05$ in both cases, Table 1). However, there were no significant differences between clutch sizes and breeding values of kestrels nesting in shrublands and the other two habitats types ($P > 0.05$ in all cases, Table 1).

Considering only the three habitats with the greatest numbers of breeding pairs, clutch size of kestrels decreased seasonally in cereal croplands ($r_S = -0.65$, $P < 0.05$, $N = 19$), and marginally in pasturelands ($r_S = -0.30$, $P < 0.06$, $N = 39$) and shrublands ($r_S = -0.55$, $P < 0.06$, $N = 13$); however, correlation coefficients did not vary significantly among the habitat types ($P > 0.05$ in all the cases).

DISCUSSION

Our results suggested that habitat features can influence the breeding biology of Eurasian Kestrels. Previous studies in northern latitudes have reported effects of habitat on food preferences (Pettifor 1984) and breeding rates (Valkama et al.

Table 1. Mean Julian egg laying dates and reproductive rates ($\bar{x} \pm$ SD) of Eurasian Kestrels in relation to habitat type. Sample size in each habitat type is shown in parentheses.

	FALLOWLAND	CEREAL CROPLAND	HOLM OAKLAND	OLIVE ORCHARDS	PASTURELAND	IRRIGATED CROPLAND	SHRUBLAND
Laying date	147.6 ± 4.3 (5)	148.7 ± 11.9 (19)	149.0 ± 2.3 (4)	137.5 ± 12.0 (2)	145.6 ± 13.6 (39)	156.3 ± 18.8 (4)	134.2 ± 35.2 (15)
Clutch size	3.8 ± 1.5 (6)	3.7 ± 1.4 (33)	4.0 ± 1.6 (9)	4.7 ± 0.6 (3)	4.4 ± 1.1 (65)	3.0 ± 1.8 (4)	4.5 ± 0.9 (16)
Hatching success (%)	87.5 ± 25.0 (4)	76.1 ± 37.9 (31)	81.2 ± 37.2 (8)	100.0 ± 0.0 (3)	85.8 ± 27.6 (59)	77.5 ± 3.5 (2)	88.2 ± 17.2 (16)
Breeding success	3.8 ± 1.9 (4)	2.9 ± 1.9 (31)	3.9 ± 1.9 (8)	4.7 ± 0.6 (3)	3.9 ± 1.6 (59)	3.5 ± 0.7 (2)	3.9 ± 0.9 (18)
Fledglings per successful nest	4.7 ± 0.6 (3)	3.5 ± 1.4 (26)	4.4 ± 1.3 (7)	4.7 ± 1.3 (3)	4.2 ± 1.3 (56)	3.5 ± 0.7 (2)	3.9 ± 0.9 (18)

1995), but our study was the first to show effects of habitat on the reproduction of Eurasian Kestrels in the Mediterranean region. Our results demonstrate the influence of farming practices on kestrel populations which have been indicated to be the principal cause for declines of European Kestrels in the Palearctic region (Tucker and Heath 1994). In the Serena region, kestrels nesting in the natural pasturelands showed higher clutch sizes and breeding success than kestrels nesting in such agricultural habitats as cereal croplands, indicating that intensification of farming practices in the Mediterranean area may have caused declines in breeding populations of Eurasian Kestrels.

Avilés and Costillo (1998) reported poor insect abundance in cereal croplands but pasturelands in the study area had the highest middle and large insect abundances. Kestrels mainly feed on middle and large insects in the central portion of Iberia (Veiga 1982) so kestrels nesting in pasturelands probably had higher food availability than kestrels nesting in croplands which may have resulted in the larger clutch sizes we observed (Martin 1987, Arcese and Smith 1988). However, we cannot confirm that the differences in breeding rates between pasturelands and cereal croplands were mediated by food availability because we did not determine the availability of the prey types in the study area.

Our results showed that, as in northern Palearctic regions, agriculture can be a major factor in the decline of breeding populations of kestrels in southern areas of Europe. Although Spain is probably one of the main strongholds for the Eurasian Kestrel in Europe (Tucker and Heath 1994) and the breeding population appears to have been stable since the 1970s (Aparicio 1997), conservation measures ensuring the maintenance of traditional pastoral forms of agriculture will probably favor the species in future years.

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LITERATURE CITED

APARICIO, J.M. 1994a. The seasonal decline in clutch size: an experiment with supplementary food in the kestrel, *Falco tinnunculus*. *Oikos* 71:451–458.

———. 1994b. The effect of variation in the laying interval on proximate determination of clutch size in the European Kestrel. *J. Avian Biol.* 25:275–280.

———. 1997. Cernícalo Vulgar. Pages 130–131 *in* F. Purroy [ED.], Atlas de la aves de España: 1975–1995. Lynx Edicions, Barcelona, Spain.

———. 1998. Individual optimization may explain differences in breeding time in the European Kestrel. *J Avian Biol.* 29:121–128.

ARCESE, P. AND J.N.M. SMITH. 1988. Effects of population density and supplemental food on reproduction in Song Sparrow. *J. Anim. Ecol.* 57:119–136.

AVILÉS, J.M. AND E. COSTILLO. 1998. Selection of breeding habitats by the Roller (*Coracias garrulus*) in farming areas of the south-western Iberian Peninsula. *Vögelwarte* 39:242–247.

———, J.M. SÁNCHEZ, A. SÁNCHEZ, AND D. PAREJO. 1999. Breeding biology of the roller *Coracias garrulus* in farming areas of the southwest Iberian Peninsula. *Bird Study* 46:217–223.

———, ———, AND ———. 2000. Breeding biology of the European Kestrel in steppes of southwestern Spain. *J. Raptor Res.* 34:45–48.

CLUTTON-BROCK, T.H. [ED.]. 1988. Reproductive success Univ. Chicago Press, Chicago, IL U.S.A.

CRAMP, S. AND K.E.L. SIMMONS. [EDS.]. 1980. Handbook of the birds of Europe, the Middle East and North Africa. Oxford Univ. Press, Oxford, U.K.

GIL-DELGADO, J.A., J.A. VERDEJO, AND E. BARBA. 1995. Nestling diet and fledgling production of Eurasian Kestrels (*Falco tinnunculus*) in eastern Spain. *J. Raptor Res* 29:240–244.

MARTIN, T.E. 1987. Food as a limit on breeding birds: a life-history perspective. *Annu. Rev. Ecol. Syst.* 18:453–487.

MØLLER, A.P. 1989. Parasites, predators and nest boxes: facts and artefacts in nest box studies of birds? *Oikos* 56:421–423.

PETTIFOR, R.A. 1984. Habitat utilization and the prey taken by kestrels in arable fenland. *Bird Study* 31:213–216.

SHRUBB, M. 1993. The kestrel. Hamlyn Species Guides 2. Hamlyn Publishers, London, U.K.

TUCKER, G.M. AND M.F. HEATH. 1994. Birds in Europe their conservation status. BirdLife International, Cambridge, U.K.

VALKAMA, J., E. KORPIMÄKI, AND P. TOLONEN. 1995. Habitat utilization, diet and reproductive success in the kestrel in a temporally and spatially heterogeneous environment. *Ornis Fenn.* 72:49–61.

VEIGA, J.P. 1982. Ecología de las rapaces de un ecosistema Mediterráneo de montaña: aproximación a su estudio comunitario. M.S. thesis, Universidad Complutense, Madrid, Spain.

VILLAGE, A. 1990. The kestrel. T. & A.D. Poyser, London, U.K.

ZAR, J.H. 1996. Biostatistical analysis. Prentice-Hall, Princeton, NJ U.S.A.

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